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Dendrobaena hortensis (Michaelsen) (Annelida: Oligochaeta: Lumbricidae) inhabiting medieval sewers in Göttingen

Dendrobaena hortensis (Michaelsen) (Annelida: Oligochaeta: Lumbricidae) in mittelalterlichen Kloaken in Göttingen

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Zusammenfassung

Bei der Ausgrabung zweier Kloaken aus dem 13ten und 15ten Jahrhundert in Göttingen wurden lebende Tiere der Regenwurmart *D. hortensis* (Mich.) gefunden. Folgende Punkte sprechen für die Hypothese, daß die Regenwürmer im Mittelalter in die Kloaken eingeschleppt wurden und fünf Jahrhunderte lang darin überlebten: (1) Kloaken stellen ein geeignetes Habitat für die Art dar, (2) die Ausbreitung der Art vom Mittelmeerraum nach Mittel- und Nordeuropa erfolgte durch Anthropochorie, (3) ein Teil des Kloakeninhalts scheint durch die Fraßtätigkeit der Regenwürmer verändert zu sein und kann als ausreichende Nahrungsquelle für eine lebensfähige Population in den 500 Jahren angesehen werden.

1. Introduction

The excavation of sewers dating back to the 13th century and before has become an important source of knowledge about human medieval life (cf. SCHÜTTE 1984). Nowadays, earthworms inhabiting these sewers may be a living link between the ancient interests of archaeologists and the present interests of ecologists. This is exemplified by the discovery of living specimens of the lumbricid earthworm species *Dendrobaena hortensis* (Mich.) during the excavation of two sewers in Göttingen (FRG).

The restricted vertical distribution of the earthworms within a 13th century sewer at a depth of 3-3.5 m gives rise to a hypothesis on their introduction between the 13th and 15th century and their subsequent survival for more than 500 years.

The discovery of *D. hortensis* caused the collection of information about the species. This again leads to some comments on its nomenclature in German species lists and keys to earthworm identification. In addition, published records of *D. hortensis* in Germany are reported and described in the context of the species' distribution throughout Europe.

We wish to thank Prof. A. Zicsi, Budapest, for checking the determination of *D. hortensis*. S. Schütte M. A., Stadtarchäologie Göttingen, kindly provided material about the sewers.

2. Description of the sewers

Two medieval sewers were detected during the work for the basement of a house in the centre of Göttingen and were excavated in late 1987. Living specimens of *D. hortensis* were found in both of them, but only the older and larger one is to be described in detail (for further information see BÜCHNER 1990).

The sewer (Fig. 1) was constructed approximately in the middle of the 13th century. It was 4-5 m deep, but there is some uncertainty about the position of the top between the remnants found and the present surface. The walls were standing on a frame of round wood and consisted of coarse stones that were joined by loam. Thus, the sewer was open to the underlying soil of sediments of the river Leine. The ground-water level was at varying depths below the sewer depending on the water regime of a branch of the Leine running through Göttingen, but at the time of construction the sewer may have served

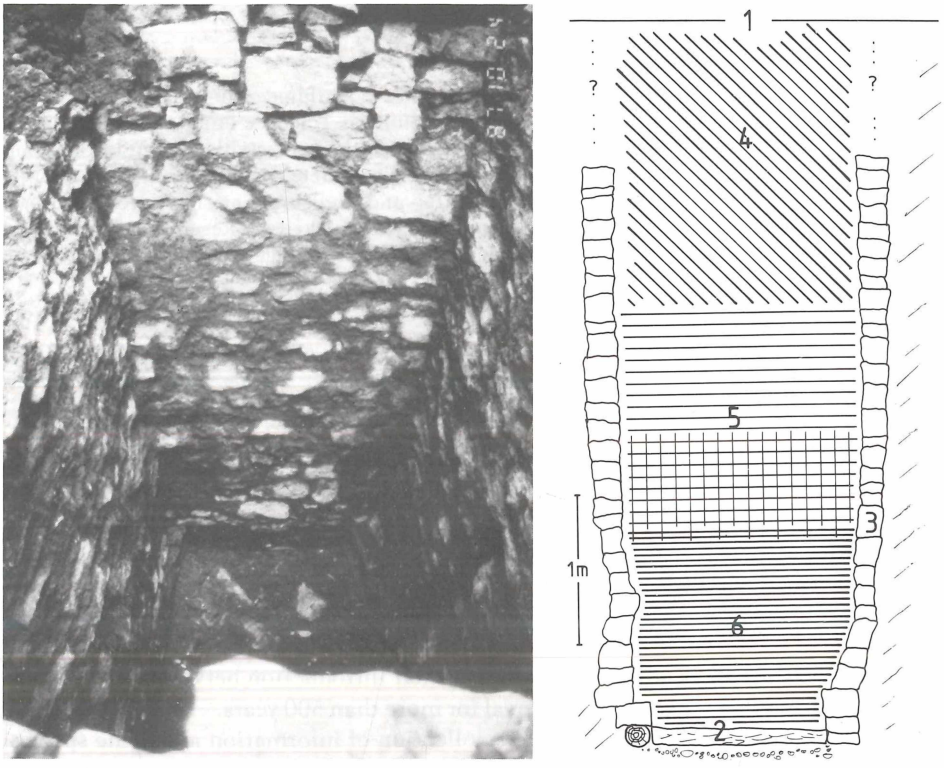

Fig. 1: 13th century sewer in Göttingen.
Left: view from top into excavated sewer;
right: sewer in longitudinal section;
1 - present surface, 2 - underlying frame of round timber, 3 - stone wall, 4 - sealing with rubble and sand, 5 - brown upper organic layer (vertical hatching: distribution of living specimens of *D. hortensis*), 6 - green lower organic layer; modified after an original from S. SCHÜTTE, Stadtarchäologie Göttingen.

as a fountain which was used for its later purpose after a drop of the ground-water level (SCHÜTTE, pers. comm.).
The content of the sewer was mainly human feces together with kitchen rubbish. The upper layer was rubble with sand. The organic content consisted of two distinct layers: the upper one was dark brown and crumbly, the lower one was greenish, solid and rather undecomposed.
The earthworms were found in the upper layer at a depth of about 3-3.5 m below the present surface. According to archaeological finds the last filling of the sewer before being sealed up with rubble was dated back between the middle of 14th to the beginning of 15th century.
The second sewer constructed in the 15th century was situated about 8 m beside the first one. Its structure was similar to the former one, but it was only 3 m deep.

3. Remarks on *D. hortensis*

In Table 1 the external characters of *D. hortensis* according to a recent key to earthworm identification are compared to a specimen found in the older sewer. Besides the characters in Table 1, the distances of setae (post-clitellar ratios aa : ab : bc : cd : dd = 1.5 : 1 : 1.5 : 1 : 3) are characteristic of *D. hortensis*. An adult specimen of *D. hortensis* found in the

Table 1: External characters of *D. hortensis*

	length [cm]	width [mm]	clitellum	tubercula pubertatis	first dorsal pore
key:	2-5	1.5-5	(26)27-33	(½29)30-31(½32)	5/6
found:	4.5	2	½27-½33	½29-½32	5/6

key: SIMS & GERARD (1985)

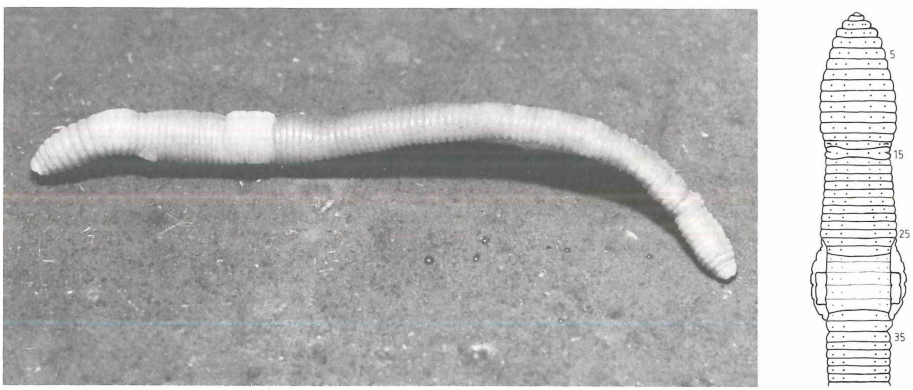

Fig. 2: *Dendrobaena hortensis* (Mich.).
Left: Lateral view of a specimen found in a sewer, preserved in 5% formaldehyde solution.
Right: Ventral view of anterior half with external characters, numbers referring to segments (modified after SIMS & GERARD 1985).

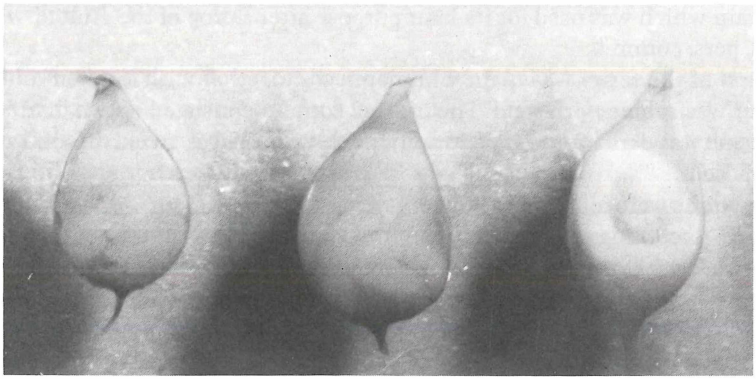

Fig. 3: Cocoons of *Dendrobaena hortensis* (Mich.).
The cocoons are smooth, light green or brown, pear-shaped, and 3-3.5 mm in length; one end has a single long fibre, the other end has several short fibres. There is one embryo per cocoon (cf. ZICSI 1985).

smaller sewer is shown in Fig. 2. Cocoons of *D. hortensis* found by thorough handsorting of crumbly material from the large sewer are shown in Fig. 3.
All specimens in the smaller sewer (7 found) had a reddish dorsal pigmentation, whereas most specimens in the larger sewer (25 found) were unpigmented. The absence of dorsal pigmentation in *D. hortensis* is frequently observed (ZICSI, pers. comm.).

3.1. Nomenclature

Externally, *D. hortensis* differs from its congeneric *D. veneta* (Rosa) only by the latter being larger (5-15 cm). Furthermore, *D. hortensis* has been regarded as a subspecies of *D. veneta* for some time and has also been ascribed to the genus *Eisenia* or *Allolobophora* (cf. ZICSI 1982). Thus, the nomenclature in two frequently used keys for Germany (FÜLLER 1976, SCHAEFER 1984) has to be corrected for *Dendrobaena hortensis* (Mich.) when referring to *Eisenia veneta* (R.).
Also, in the latest lumbricid species list for Germany (GRAFF 1983, p.18) *D. veneta* has to be replaced by *D. hortensis* (GRAFF, pers. comm.). *D. veneta* is known in Germany only from a greenhouse in Berlin (WILCKE 1941) and possibly from an earthworm farm in Baden (GRAFF, pers. comm.). In GRAFF's (1983) species list it is represented by its abandoned name *Dendrobaena austriaca* (synonym: *Eisenia austriaca* Mich., cf. ZICSI 1982).

3.2. Distribution

Including this study only 5 published records of *D. hortensis* in Germany are available (Fig. 4a). GRAFF (1954) reports its occurrence in greenhouses in Hamburg and Braunschweig. WILCKE (1941) describes the species to be part of a collection at the zoological museum in Berlin with 'near the zoological museum' being the sample site. One specimen was found by RABELER (1960) under the bark of a decaying tree trunk in a

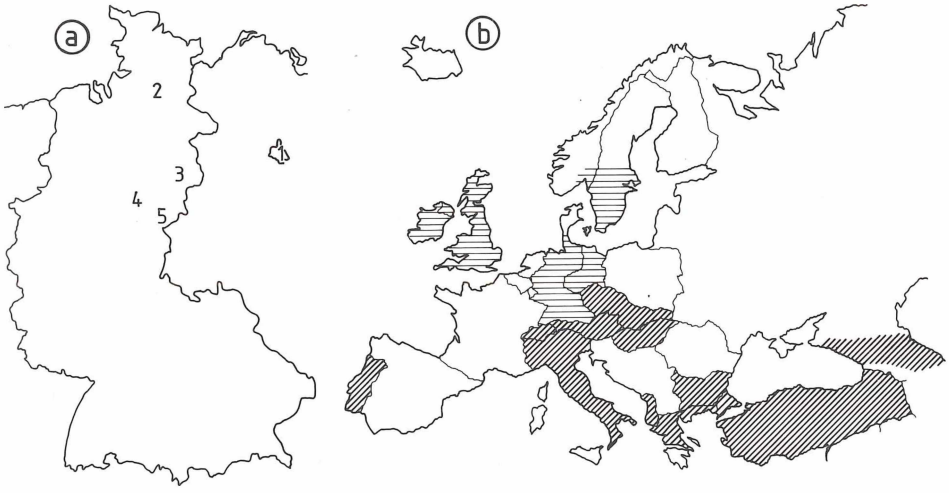

Fig. 4: Distribution of *Dendrobaena hortensis* (Mich.).
a) German records by WILCKE (1941, no.1), GRAFF (1954; nos. 2 & 3), RABELER (1960; no.4), and this study (no.5).
b) European records according to Table 2;
cross hatched: mainland of countries with no indication of anthropochorous origin; horizontally hatched: countries with anthropochorous introductions, northern limits in Sweden and Norway after STÖP-BOWITZ (1969).

Melico-Fagetum elymetosum near Beverungen/Weser (named *Eisenia veneta* R., see above for nomenclature).
D. hortensis has been described as introduced via greenhouses and gardens for Great Britain and Ireland (SIMS & GERARD 1985), Norway (STÖP-BOWITZ 1969) and Sweden (JULIN 1950). The original distribution is either said to be the mediterranean region (GRAFF 1954), or southern and western Europe (WILCKE 1941). ZICSI (1985) regards the Caucasus and the Near East to be the origin of the *D. veneta* species complex (including *D. hortensis*).
The European distribution of *D. hortensis* is compiled in Table 2 and Fig. 4b.

Table 2: Records of *D. hortensis* in Europe

country	anthropochorous origin	author(s)
USSR (Caucasus), Turkey, Greece, Albania, Italy, Switzerland, Portugal		SIMS & GERARD 1985
Bulgaria		ZICSI & CSUZDI 1986
Hungary		ZICSI 1959
Tchechoslovakia		ZAJONC 1981
Austria		ZICSI 1965
Germany	+	GRAFF 1954
Great Britain, Ireland	+	SIMS & GERARD 1985
Sweden	+	JULIN 1950
Norway	+	STÖP-BOWITZ 1969

WILCKE (1941) describes its German distribution as resulting from a successive dispersal from the south/west European origin. This dispersal is most probably anthropochorous (GRAFF 1954: adventitious faunal element), if the species' preferred habitats (cf. 3.3 below) and the actual habitats in Germany as well as introductions into other northern countries are taken into account. Thus *D. hortensis* is distributed together with garden- and greenhouse-plants or compost and may have invaded other suitable habitats subsequently. This is the supposed mechanism of its introduction into South Africa, India, South and North America, too (cf. SIMS & GERARD 1985).

3.3. Medieval sewers as a habitat

The preferred habitat of *D. hortensis* is compost soil (ZICSI 1965), but it feeds on rotten wood, leaf litter or feces of hares and cattle also (ZICSI 1985). This is supported by SIMS & GERARD (1985), who describe decaying forest litter and organic rich soils (greenhouses, gardens, pastures) as habitats and report the species 'near septic tank and [in] wet soils recently treated with sewage' as well.

Thus, the sewer described above represents a suitable habitat for the species, and an introduction with vegetable rubbish at medieval times seems to be probable. On the other hand, an active immigration in recent times is rather improbable as both the walls and soil surrounding the sewer and the thick layer of rubble sealing the top are either impenetrable or a hostile medium to *D. hortensis*.

The upper layer of the sewer's content seems to result from the earthworms' feeding on undecomposed material, which is still present in the lower layer. Hence, a volume of about 3 m^3 of organically rich material must have been the nutritive source of a *D. hortensis* population of unknown size for at least 500 years (15th-20th century).

Taking a specific density of 1.5 g/cm^3 of the organic material and a consumption of 8-20 g per worm and year (as measured by Guild for three lumbricid species feeding on cow dung, EDWARDS & LOFTY 1977, p.172), we get:

$3*10^6\ cm^3 * 1.5\ g*cm^{-3} / 500\ a / (8 \text{ or } 20)\ g*a^{-1}$,

i. e. between 1125 and 450 individuals of *D. hortensis* as an average population density in the sewer. Thus, the crumbly upper organic layer can be regarded as a food source sufficient to have sustained a large viable earthworm population during the long time of five centuries.

The hypothesis of an introduction and survival of earthworms into medieval sewers also is supposed to be an explanation for the occurence of *Helodrilus oculatus* Hoffmeister in a similar sewer in Zürich that was tightly sealed by a cover of fitted stones (JUNGEN 1982).

A sufficient oxygen supply for the animals living at the considerable depth of more than 3 m is an interesting point, especially as the lower organic layer was undecayed, i. e. there was an oxygen deficiency in this lower layer. Anyway, as earthworms did live in the substrate in recent times, oxygen supply obviously was sufficient down to the transition of the upper crumbly to the lower solid organic layer.

A related phenomenon of earthworms inhabiting a deep soil layer was reported by DOBSON & SATCHELL (1956): specimens of *Eophila oculata* (Hoffm.) (= *H. oculatus*) were found in a former ditch 2.4-4.5 m below ground-level. The ditch was filled in the 1st century and sealed by buildings in the 1st to the 4th centuries. The earthworms are sup-

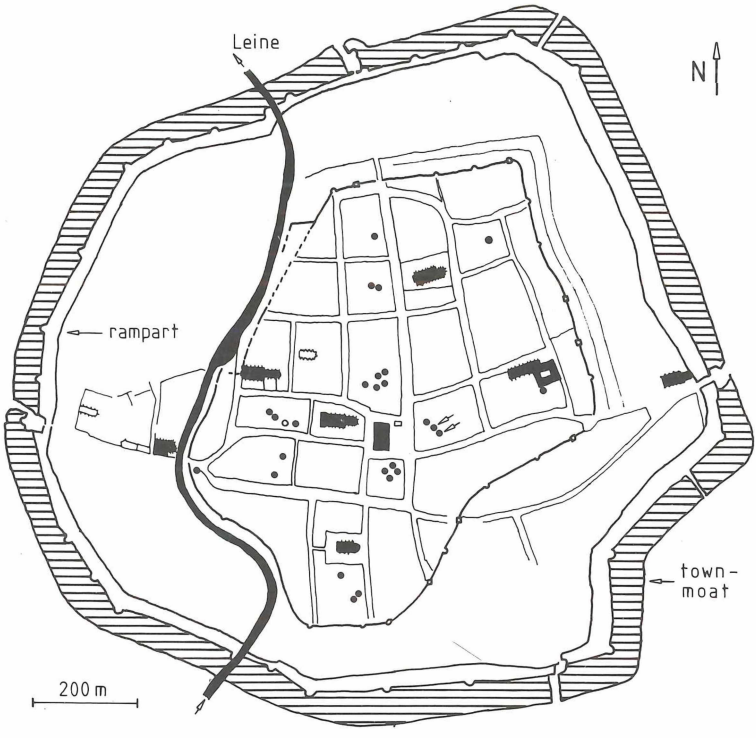

Fig. 5: Map of medieval Göttingen;
black circles: location of sewers discovered to date, arrows indicating sewers of this study; open circle: unidentified earthworms found during a former excavation; sewers differ in age and size; town hall and churches in black; after SCHÜTTE (1984 and pers. comm.).

posed to have entered the ditch before filling and to have bred in the deep layer for more than 1800 years despite obviously restricted oxygen supplies.
So far, numerous medieval sewers have been found in Göttingen (Fig. 5), and many more can be supposed to be still undetected. *D. hortensis* may have been introduced into all these sewers, and the probably long time of the populations' isolation could provide an interesting field of investigation for population geneticists. The loss of pigmentation of most earthworms found in the older sewer compared to the throughout reddish pigmentation of animals in the smaller sewer may be an indication of a genetic differentiation between the isolated populations.

4. Summary

During the excavation of a 13th and a 15th century sewer in the township of Göttingen living specimens of *D. hortensis* (Mich.) were discovered. There is evidence for the hypothesis that the earthworms were introduced into the sewers in the Middle Ages and have survived therein for five centuries: (1) sewers are suitable habitats for the species, (2) the dispersal of the species from the mediterranean region into mid and north European countries has been via anthropochory, (3) a part

of the sewers' content seems to be modified by earthworm nutrition and would have been sufficient to sustain a viable population for 500 years.

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